NAFO Sci. Coun. Studies, 18: xx–xx

The Feeding of Cod (*Gadus morhua*) on Flemish Cap, 1989–90

J. Paz, J. M. Casas, and G. Perez-Gándaras
Instituto de Investigacions Marinas, Eduardo Cabello 6
36208 Vigo, Spain

Abstract

The food and feeding of Flemish Cap cod (*Gadus morhua*) in summer are described for 2 years, 1989 and 1990. The summer feeding intensity was high and the prey spectrum was narrow in both years. Hyperidea and redfish stood out in the diet of the Flemish Cap cod. *Illex illecebrosus* and polychaetes had a high annual variability. In the juvenile cod diet, invertebrates (crustaceans and polychaetes) were dominant and in the adults the most important prey were fish, mainly redfish. The Schoener overlap index was calculated to study the intraspecific diet overlap. It was noted that cod diet changed between age groups 3-5 and 6-10. Cannibalism rates showed year-to-year fluctuations. Ingestion of redfish was similar in both years and a direct relationship between cod length and the length of redfish they preyed on was noted.

Introduction

The quality and quantity of food intake by fish are known to be important factors for their growth, maturity and fecundity changes. Cannibalism and predation on other juveniles are also important factors on recruitment patterns of fish stocks. Predation by cod on smaller cod and redfish may produce variable mortalities in juveniles, and contribute to the variations in year-class strength (Akenhead, MS 1978; Lilly, 1987).

This study is aimed at determining food and feeding patterns of cod (*Gadus morhua*) on the Flemish Cap (NAFO Div. 3M). Although sampling was limited to the summer period, the months studied correspond to the period of highest feeding intensity (Turuk, MS 1981). It is also known that the diet of cod on the Flemish Cap is not very different during the rest of the year (Albikovskaya and Gerasimova, MS 1989).

Materials and Methods

Random-stratified bottom trawl surveys were carried out by the European Economic Community on Flemish Cap in July 1989 and July–August 1990. Although the vessels were different in the 2 years: *RV Cryos* in 1989 and *Ignat Paulichenkov* in 1990, standardized survey procedures were used, and these are described by Vazquez (MS 1990, MS 1991). Biological samples were collected during both research surveys, and they included some small cod fry caught in a few pelagic trawls. Total length of cod were measured to the nearest centimeter and each individual was weighed to ±5 g. Otoliths were extracted and used to age the cod in the laboratory. Samples were then classified by age groups.

A total of 1 182 in 1989 and 530 in 1990 cod stomachs were collected and frozen on board (Table 1). In the laboratory the stomachs were thawed and stomach contents were examined. The food components were first separated and identified as far as possible. Food items in each taxon were then placed briefly on absorbent paper to remove excess liquids, and weighed to a precision of ±.01 g. For cod grouped in age-groups, the following indices were calculated:

The Feeding Intensity Index (FI) was obtained from:

$$FI = \frac{SN_f}{SN_t}$$

where SN_f is the number of stomachs containing some food, and

SN_t is the total number of stomachs analyzed.

Prey Occurrence Index (OCI) was taken as the relationship between the number of stomachs with a prey in the total number of stomachs analyzed.

A Gravimetric Index (GI) was obtained from the expression: total weight of a specific prey in all stomachs as a percentage of total weight of all prey.

Stomach Fullness Index was obtained by calculating the Mean Total Fullness Index (TFI):

$$TFI = \frac{1}{n} \sum_{f=1}^{n} \frac{f_w}{f_1^3} \cdot 10^4$$

where n is the number of stomachs examined,

f_w is weight of stomach contents of the fish f, and

f_1 is the length of the fish f.

and the Mean Partial Fullness Index of prey "p" (PFI):

$$PFI = \frac{1}{n} \sum_{f=1}^{n} \frac{f_p}{f_1^3} \cdot 10^4$$

where f_p is weight of the prey p in the stomach of the fish f.

The Simpson's Feeding Diversity Index (D) was obtained from:

$$D = 1 - \sum_{i=1}^{s} \frac{N_i (N_i - 1)}{N(N-1)}$$

when N_i is the number of times in which the type of prey appears in the total number of stomachs,

N is the number of times in which all prey appear in the total number of stomachs, and

s is the number of types of prey.

The Condition Factor was studied with Fulton's expression:

$$CF = \frac{W\ 100}{L^3}$$

where W is fish weight, and

L is the length of the fish.

Diet Overlap Index was obtained from Schoener diet overlap index (R_o) (Linton *et al.*, 1981) given as

$$R_o = 1 - \frac{1}{2} \sum_{i=1}^{n} | P_{ij} - P_{ik} |$$

where P_{ij} is the frequency of appearance of the prey i in the individuals of the class j,

P_{ik} is the frequency of appearance of the prey i in the individuals of the class k.

The diet overlap was calculated intraspecifically (Wallace and Ramsey, 1983). This index was calculated between three cod age groups: A = 1 and 2 years old; B = 3, 4 and 5 years old; and C = 6 or more years old. Following Mathur (1977), the value accepted as a limit to consider that diets overlapped was $R_o > 0.6$.

The Cannibalism Index was calculated as an occurrence index for cod prey. The rates were compared with data from a similar survey obtained in 1988 (Paz *et al.*, MS 1989). For statistical analyses using the Kruskal-Wallis test, distribution data were transformed to natural logarithms.

Whenever stomach content data on redfish were not seriously affected by digestion, feeding patterns of cod on redfish were studied utilizing total lengths of redfish measured to the nearest centimeter. When this was not possible, the jaw bones of redfish in the stomach contents were measured to the nearest millimeter and a linear regression used to obtain the relationship of jaw length to total length of the redfish. Only the 3, 4, 5 and 6 age groups were suitable for comparing data from the 2 years because the sample sizes were similar.

Results and Discussion

Feeding patterns. The feeding intensity is presented in Table 2: it was similar in both years. For the 3 to 6 age groups the intensity was higher in 1990. In Tables 3 and 4, the food components are shown distributed into cod age groups. The variety of prey organisms was small, and this was in accordance with the narrow prey spectrum of Flemish Cap cod (Konstantinov et al., MS 1983).

Both the OCI (Tables 5 and 6) and the GI (Tables 7 and 8) indicated amphipod dominance in the younger age groups (2, 3 and 4). The value of the gravimetric index for the amphipods was larger than 60% in both years. The figures for age 5 were different in the 2 years: in 1989 the GI value was 27.07 for amphipods and 70.32 for fish, and in 1990 78.42 and 14.30, respectively. Polychaetes were not found in the older fish in 1990. The high GI value of cephalopods in 1990 corresponded with the great abundance of squid, *Illex illecebrosus*, in survey catches that year (Vazquez, MS 1991).

The TFI and PFI are shown in Tables 9 and 10. They confirm the greater importance of polychaetes and cephalopods in 1990 compared with 1989. For the comparable ages (3, 4, 5 and 6) fish were more important in the 1989 cod diet.

A Kruskal-Wallis Test indicated that ingestion of redfish was similar in both years. Other important prey with high occurrence levels, such as Hyperiidae, Pandalus borealis and other Crustacea, were dissimilar between two years. So also were cod, polychaetes and squids, all with significant differences at $P > 0.01$. Fishes were incorporated into the diet at age 2 in 1989 and at age 3 in 1990, and their presence in both years increased with age (Tables 9 and 10). Redfish was the more important fish prey. It is interesting to note that the age group 0 cod also preyed on redfish larvae,

TABLE 1. Numbers of cod stomachs at age collected during July 1989 and July/August 1990 surveys on Flemish Cap (NAFO Div. 3M).

	Age group									
	0	1	2	3	4	5	6	7	8	9+
1989	–	7	7	242	467	387	55	9	6	2
1990	14	30	85	44	106	103	86	28	17	17

TABLE 2. The Food Intensity Index of cod by age in Div. 3M in July 1989 and July/August 1990.

	Age group									
	0	1	2	3	4	5	6	7	8	9+
1989		0.857	0.857	0.955	0.938	0.899	0.891	1	1	1
1990	1	0.966	1	1	0.972	0.981	1	1	0.944	0.944

average 1989 (3-6 years): 0.921 ± 0.0307

average 1990 (3-6 years): 0.988 ±0.0140

TABLE 3. Food items observed in the stomachs of cod, by age in Div. 3M in July 1989.

	Age group							
Food items	1	2	3	4	5	6	7	8+
Class Ctenophora				+	+			
Class Anthozoa								
O. Actinida			+	+	+			
Class Polychaeta								
O. Errantia			+		+	+		
Class Crustacea								
O. Isopoda				+				
O. Copepoda			+	+	+			
O. Amphipoda	+	+	+	+	+	+	+	
O. Decapoda								
Pandalus borealis		+	+	+	+	+	+	
Other decapoda			+	+				
Class Bivalva				+				
Class Cephalopoda								
Illex illecebrosus			+	+	+			
Class Ophiuroidea				+				
Class Echinoidea				+	+			
Class Asteroidea				+				
Class Pisces								
Fam. Scorpaenidae								
Sebastes spp.			+	+	+	+	+	+
Fam. Gadidae								
Gadus morhua				+	+	+		
Fam. Serrivomeridae			+	+	+	+		
Fam. Anarhichadidae								
Anarhichias sp.			+	+	+	+	+	
Anarhichias lupus			+	+	+			
Anarhichias denticulatus					+			
Fam. Myctophidae				+	+			
Other pisces			+	+	+			
Eggs of pisces				+				

TABLE 4. Food items observed in the stomachs of cod, by age in Div. 3M in July/August 1990.

	Age group									
Food items	0	1	2	3	4	5	6	7	8	9+
Class Polychaeta										
O. Errantia		+	+	+	+	+	+			
Fam. Aphroditidae			+	+	+	+				
Class Crustacea										
O. Copepoda	+	+	+	+	+					
O. Amphipoda	+	+	+	+	+	+	+	+	+	
Fam. Gammaridae		+	+		+	+	+			
O. Decapoda										
Pandalus borealis		+	+	+	+	+	+	+	+	+
Pagurus sp.					+		+			
Fam. Maiidae					+	+				+
Class Gasteropoda						+				+
Class Bivalva										+
Class Cephalopoda[a]			+		+	+	+	+	+	
Class Ophiuroidea			+			+	+			+
Class Holoturoidea							+			
Class Ascidiacea							+			
Class Pisces										
Fam. Scorpaenidae										
Sebastes spp.	+		+	+		+	+	+	+	+
Fam. Gadidae										
Gadus morhua					+	+	+	+		
Fam. Stichaeidae										
Lumpenus sp.			+			+	+			
Fam. Cottidae										
Triglops murrayi			+							
Fam. Macrouridae										
Nezumia bairdi							+			
Fam. Anarhichadidae					+	+				+
Fam. Myctophidae			+		+	+				
Other pisces						+		+		

[a] Mainly *Illex illecebrosus*

TABLE 5. The Occurrence Index of food items of cod, by age in Div. 3M in July 1989.

	Age group									
Food items	1	2	3	4	5	6	7	8	9+	Total
Class Anthozoa										
O. Actinida	–	–	0.004	0.002	0.003	–	–	–	–	0.002
Class Ctenofora	–	–	–	0.002	0.003	–	–	–	–	0.002
Class Polychaeta	–	–	0.016	–	0.005	0.018	–	–	–	0.006
Phylum Echinodermata	–	–	–	0.009	0.003	–	0.111	–	–	0.005
Phylum Mollusca										
Class Cephalopoda[a]	–	–	0.025	0.013	0.013	–	–	–	–	0.014
Other Mollusca	–	–	–	0.004	0.003	–	–	–	–	0.002
Mollusca Total	–	–	0.025	0.017	0.016	–	–	–	–	0.016
Class Crustacea										
O. Copepoda	–	–	0.45	0.011	0.008	–	–	–	–	0.016
Fam. Hyperidae	0.14	0.57	0.839	0.694	0.486	0.163	0.222	–	–	0.618
O. Decapoda										
Pandalus borealis	–	0.143	0.07	0.107	0.145	0.127	0.222	–	–	0.112
Other crustacea	–	0.286	0.012	0.017	0.005	–	–	–	–	0.012
Crustacea Total	0.14	0.999	1.371	0.829	0.644	0.290	0.444	–	–	0.758
Class Pisces										
Sebastes spp.	–	–	0.012	0.122	0.284	0.491	0.444	1	1	0.017
Gadus morhua	–	–	–	0.002	0.003	0.018	–	–	–	0.002
Anarhichias sp.	–	–	0.008	0.009	0.023	0.018	0.111	–	–	0.014
Fam. Myctophidae	–	–	–	0.009	0.008	–	–	–	–	0.006
Fam. Cottidae	–	–	0.004	–	–	–	–	–	–	0.001
Fam. Macrouridae	–	–	–	–	0.005	–	–	–	–	0.002
Other pisces	–	–	0.004	0.013	0.008	0.018	–	–	–	0.005
Unidentified	–	–	0.045	0.124	0.196	0.218	0.444	–	–	0.136
Pisces Total	–	–	0.073	0.279	0.527	0.763	0.999	1	1	0.343
Other prey	0.714	–	0.074	0.058	0.044	0.018	–	–	–	0.057
Total	0.854	0.999	1.563	1.196	1.245	1.089	1.554	1	1	1.189
No. Stomachs	7	7	242	467	387	55	9	8	2	1182
% empty stomachs	14.3	14.3	4.5	6.2	10.1	10.9	0	0	0	7.36

[a] Mainly *Illex illecebrosus*.

TABLE 6. The Occurrence Index of food items of cod, by age in Div. 3M in July/August 1990.

	Age group										
Food items	0	1	2	3	4	5	6	7	8	9+	Total
Class Anthozoa											
O. Actinida	–	–	–	–	–	–	–	–	–	–	–
Class Ctenofora	–	–	–	–	–	–	–	–	–	–	–
Class Polychaeta	–	0.03	0.15	0.09	0.12	0.07	0.05	–	–	–	0.079
Phylum Echinodermata	–	–	0.01	–	–	0.01	0.01	–	–	–	0.006
Phylum Mollusca											
Class Cephalopoda[a]	–	–	0.02	–	0.02	0.13	0.08	0.04	0.06	–	0.049
Other Mollusca	–	–	–	–	–	0.02	–	–	–	–	0.007
Mollusca Total	–	–	0.02	–	0.02	0.15	0.08	0.04	0.06	–	0.056
Class Crustacea											
O. Copepoda	0.21	0.20	0.05	0.04	0.01	–	–	–	–	–	0.030
Fam. Hyperidae	0.43	0.83	0.87	0.93	0.93	0.91	0.48	0.18	0.18	–	0.732
O. Decapoda											
Pandalus borealis	–	0.23	0.27	0.34	0.28	0.23	0.33	0.14	0.18	0.12	0.257
Other crustacea	0.21	0.03	0.05	0.02	0.05	0.05	0.05	–	–	0.06	0.045
Crustacea Total	0.85	1.29	1.24	1.33	1.27	1.19	0.86	0.32	0.36	0.18	1.064
Class Pisces											
Sebastes spp.	0.36	–	0.01	0.02	–	0.07	0.46	0.82	0.82	0.76	0.196
Gadus morhua	–	–	–	–	0.01	0.07	0.06	0.07	–	–	0.028
Anarhichias sp.	–	–	–	–	0.01	0.02	–	–	–	0.06	0.007
Fam. Myctophidae	–	–	0.01	–	0.01	0.02	–	–	–	–	0.007
Fam. Cottidae	–	–	0.01	–	–	–	–	–	–	–	0.002
Fam. Macrouridae	–	–	–	–	–	–	0.01	–	–	–	0.002
Other pisces	–	–	0.01	–	–	0.02	0.01	0.04	–	–	0.004
Unidentified	–	–	0.02	0.02	0.07	0.16	–	0.06	–	0.18	0.075
Pisces Total	0.36	–	0.06	0.04	0.10	0.36	0.54	0.99	0.82	1.00	0.321
Other prey	0.07	0.03	0.03	0.02	0.02	0.04	0.03	–	–	–	0.028
Total	1.28	1.35	1.51	1.48	1.53	1.82	1.57	1.35	1.24	1.18	1.552
No. Stomachs	14	30	85	44	106	103	86	28	17	17	516
% empty stomachs	0	3.3	0	0	2.8	1.9	0	0	5.9	5.9	1.35

[a] Mainly *Illex illecebrosus*

TABLE 7. The Gravimetric Index (%) of food items of cod, by age in Div. 3M in July 1989 (* = Trace).

	Age group									
Food items	1	2	3	4	5	6	7	8	9+	Total
Class Anthozoa										
O. Actinida	–	–	0.2	*	*	–	–	–	–	0.02
Class Ctenofora	–	–	–	0.2	*	–	–	–	–	0.05
Class Polychaeta	–	–	0.44	–	0.06	0.05	–	–	–	0.05
Phylum Echinodermata	–	–	–	0.09	*	–	0.15	–	–	0.03
Phylum Mollusca										
Class Cephalopoda[a]	–	–	0.8	1.3	0.2	–	–	–	–	0.34
Other Mollusca	–	–	–	*	0.04	–	–	–	–	0.02
Mollusca Total	–	–	0.8	1.3	0.24	–	–	–	–	0.36
Class Crustacea										
O. Copepoda	–	–	0.2	*	*	–	–	–	–	0.12
Fam. Hyperidae	42.2	83.4	86.5	52.43	27.07	2.1	1.2	–	–	31.84
O. Decapoda										
Pandalus borealis	–	7.9	1.8	1.65	1.62	0.3	0.2	–	–	1.27
Other crustacea	–	8.7	0.2	0.8	0.03	–	–	–	–	1.59
Crustacea Total	42.2	100	88.7	54.88	28.72	2.4	1.4	–	–	34.82
Class Pisces										
Sebastes spp.	–	–	3.4	32.85	55.43	79.94	48.1	100	100	51.96
Gadus morhua	–	–	–	0.22	0.2	0.9	–	–	–	0.28
Anarhichias sp.	–	–	0.7	0.69	2.24	6.5	17.6	–	–	2.71
Fam. Myctophidae	–	–	–	0.09	0.1	–	–	–	–	0.07
Fam. Cottidae	–	–	0.23	–	–	–	–	–	–	0.01
Fam. Macrouridae	–	–	–	–	0.88	–	–	–	–	0.3
Other pisces	–	–	1.9	1.39	0.79	1.4	–	–	–	1.03
Unidentified	–	–	1.83	8.49	10.68	9.1	33.8	–	–	9.27
Pisces Total	–	–	8.06	43.73	70.32	97.84	99.5	1	1	65.63
Other prey	58.24	–	2.13	1.07	0.84	0.12	–	–	–	3.92
No. Stomachs	7	7	242	467	387	55	9	6	2	1 182
% empty stomachs	14.3	14.3	4.5	6.2	10.1	10.9	0	0	0	7.36

[a] Mainly *Illex illecebrosus*

TABLE 8. The Gravimetric Index (%) of food items of cod, by age in Div. 3M in July/August 1990 (* = Trace).

	Age group									
Food items	1	2	3	4	5	6	7	8	9+	Total
Class Anthozoa										
O. Actinida	–	–	–	–	–	–	–	–	–	–
Class Ctenofora	–	–	–	–	–	–	–	–	–	–
Class Polychaeta	0.22	2.30	0.49	0.69	0.19	0.02	–	–	–	1.40
Phylum Echinodermata	–	*	–	–	*	0.002	–	–	–	*
Phylum Mollusca										
Class Cephalopoda[a]	–	0.45	–	0.078	5.94	11.57	0.001	0.005	–	4.37
Other Mollusca	–	–	–	–	0.25	–	–	–	0.34	0.07
Mollusca Total	–	0.45	–	0.078	6.19	11.57	0.001	0.005	0.34	4.44
Class Crustacea										
O. Copepoda	3.58	0.20	0.05	0.006	–	–	–	–	–	*
Fam. Hyperidae	63.31	82.97	60.13	89.70	78.42	15.44	0.73	0.16	–	28.47
O. Decapoda										
Pandalus borealis	24.8	6.56	2.90	1.28	0.45	1.05	0.23	0.57	0.32	0.80
Other crustacea	4.7	0.31	0.05	0.19	0.29	2.31	–	–	3.96	1.08
Crustacea Total	96.39	90.04	63.13	91.17	79.16	18.80	0.96	0.73	4.28	30.35
Class Pisces										
Sebastes spp.	–	1.65	36.15	–	6.87	54.41	96.39	99.24	82.57	56.96
Gadus morhua	–	–	–	0.34	4.49	12.57	2.49	–	–	5.10
Anarhichias sp.	–	–	–	0.19	0.60	–	–	–	8.45	0.86
Fam. Myctophidae	–	2.74	–	0.32	0.13	–	–	–	–	0.05
Fam. Cottidae	–	2.54	–	–	–	–	–	–	–	0.03
Fam. Macrouridae	–	–	–	–	–	0.26	–	–	–	0.07
Other pisces	–	1.10	–	–	0.88	0.07	0.16	–	–	0.22
Unidentified	–	1.41	0.18	4.90	1.33	1.56	–	0.03	4.24	1.45
Pisces Total	–	9.44	36.33	5.75	14.30	68.87	99.04	99.27	95.26	64.74
Other prey	3.35	0.24	0.03	0.08	0.13	0.11	–	–	–	0.04
No. Stomachs	30	85	44	106	103	86	28	17	17	516
% empty stomachs	3.3	0	0	2.8	1.9	0	0	5.9	5.9	1.35

[a] Mainly *Illex illecebrosus*

TABLE 9. Total and Partial Fullness Index for cod by age in Div. 3M. in July 1989 (* = Trace).

	Age group								
Food items	1	2	3	4	5	6	7	8	9+
Class Anthozoa									
O. Actinida	–	–	0.001	*	*	–	–	–	–
Class Ctenofora	–	–	–	0.001	*	–	–	–	–
Class Polychaeta	–	–	0.007	–	0.001	0.001	–	–	–
Phylum Echinodermata	–	–	–	0.001	*	–	0.004	–	–
Phylum Mollusca									
Class Cephalopoda[a]	–	–	0.006	0.010	0.003	–	–	–	–
Other Mollusca	–	–	–	*	0.001	–	–	–	–
Mollusca Total	–	–	0.006	0.010	0.004	–	–	–	–
Class Crustacea									
O. Copepoda	–	–	0.004	*	*	–	–	–	–
Fam. Hyperidae	0.233	0.341	0.826	0.755	0.382	0.056	0.026	–	–
O. Decapoda									
Pandalus borealis	–	0.113	0.024	0.021	0.020	0.011	0.005	–	–
Other crustacea	–	0.097	0.002	0.006	*	–	–	–	–
Crustacea Total	0.233	0.551	0.856	0.782	0.402	0.067	0.031	–	–
Class Pisces									
Sebastes spp.	–	–	0.021	0.348	0.592	1.568	0.826	2.527	1.250
Gadus morhua	–	–	–	0.002	0.003	0.015	–	–	–
Anarhichias sp.	–	–	0.004	0.007	0.023	0.074	0.323	–	–
Fam. Myctophidae	–	–	–	0.001	0.001	–	–	–	–
Fam. Cottidae	–	–	0.002	–	–	–	–	–	–
Fam. Macrouridae	–	–	–	–	0.009	–	–	–	–
Other pisces	–	–	0.010	0.019	0.009	0.039	–	–	–
Unidentified	–	–	0.018	0.105	0.133	0.173	0.848	–	–
Pisces Total	–	–	0.055	0.482	0.770	1.869	1.997	2.527	1.250
Other prey	0.294	–	0.024	0.017	0.011	0.003	–	–	–
Total Fullness Index	0.527	0.551	0.941	1.292	1.183	1.940	2.016	2.527	1.250
No. Stomachs	7	7	242	467	387	55	9	8	2
% empty stomachs	14.3	14.3	4.5	6.2	10.1	10.9	0	0	0

[a] Mainly *Illex illecebrosus*

TABLE 10. Total and Partial Fullness Index for cod by age in Div. 3M in July/August 199 (* = Trace).

	Age group									
Food items	0	1	2	3	4	5	6	7	8	9+
Class Polychaeta	–	0.002	0.036	0.015	0.013	0.004	0.001	–	–	–
Phylum Echinodermata	–	–	*	–	–	*	*	–	–	–
Phylum Mollusca										
Class Cephalopoda[a]	–	–	0.008	–	0.002	0.111	0.130	*	*	–
Other Mollusca	–	–	–	–	–	0.003	–	–	–	0.003
Mollusca Total	–	–	0.008	–	0.002	0.114	0.130	*	*	0.003
Class Crustacea										
O. Copepoda	0.676	0.055	0.004	0.001	*	–	–	–	–	–
Fam. Hyperidae	0.864	0.787	1.207	1.566	1.524	1.523	0.370	0.034	0.006	–
O. Decapoda										
Pandalus borealis	–	0.242	0.115	0.072	0.027	0.009	0.022	0.009	0.013	0.003
Other crustacea	0.410	0.037	0.004	0.002	0.005	0.007	0.064	–	–	0.045
Crustacea Total	1.950	1.121	1.330	1.641	1.556	1.539	0.456	0.043	0.019	0.048
Class Pisces										
Sebastes spp.	1.885	–	0.016	–	–	0.115	0.968	2.382	1.712	0.891
Gadus morhua	–	–	–	–	0.038	0.085	0.147	0.111	–	–
Anarhichias sp.	–	–	–	–	0.003	0.009	–	–	–	0.331
Fam. Myctophidae	–	–	0.004	–	0.007	0.003	–	–	–	–
Fam. Cottidae	–	–	0.034	–	–	–	–	–	–	–
Fam. Macrouridae	–	–	–	–	–	–	0.005	–	–	–
Other pisces	–	–	0.014	–	–	0.010	0.002	0.006	–	–
Unidentified	–	–	0.025	0.004	0.091	0.019	0.031	–	0.001	0.039
Pisces Total	1.885	–	0.093	0.004	0.139	0.241	1.153	2.499	1.713	1.261
Other prey	0.106	0.045	0.005	0.001	0.001	0.002	*	–	–	–
Total Fullness Index	4.600	1.168	1.472	1.661	1.710	1.900	1.758	2.453	1.731	1.063
No. Stomachs	14	30	85	44	106	103	86	28	17	17
% empty stomachs	0	3.3	0	0	2.8	1.9	0	0	5.9	5.9

[a] Mainly *Illex illecebrosus*

although age group 1 did not prey on redfish and age group 2 had very low predation rates.

The food diversity was very similar in both years increasing with the age until age group 6. The larger feeding diversity appeared in age groups 5, 6 and 7 (Table 11). The average for cod age groups 3-6 show higher feeding diversities than the total averages in 1989 although they were somewhat comparable in 1990.

Condition factors by age groups are given in Table 12. Their levels were high and similar for the two years. For comparable age groups, the values of the condition factor were higher in 1990.

The diet overlap calculated intraspecifically provided a better idea of the feeding similarities between the three age groups considered. The results obtained are shown in Table 13. It was noted that cod diet changed between group B and group C. With the Mathur criterion of overlap (Mathur, 1977) when the index was higher than 0.6, there was only diet overlap between groups A and B in 1990. When considered by different depths, this group index was more regular (Table 14). At 180-260 m, the diet of A and B groups was very similar, while the older groups (B and C) had the maximum value overlap index at 360 m. The maximum value overlap index for groups A–B and A–C corresponded to the 180 m. These results indicated similar trophic habits of the prerecruits and immature recruits. The diet change can be associated with the energetics of sexual maturation and the spawning process.

There was cannibalism in age groups 4 to 7 in 1990. The cannibalism index (Table 15) was greater in 1990 (4.64%) than in 1989 (0.33%) but similar to 1988 (3.78%) (Vazquez, MS 1989), however, there were strong year-to-year fluctuations. The 1990 result was higher than that obtained by Lilly (MS 1982), however, it is recognized that those results refer to winter conditions.

TABLE 11. The Food Diversity Index of cod by age in Div. 3M in July 1989 and July/August 1990.

	Age group									
	0	1	2	3	4	5	6	7	8	9+
1989	–	0.33	0.667	0.464	0.634	0.756	0.732	0.846	–	–
1990	0.797	0.590	0.631	0.552	0.586	0.704	0.739	0.571	0.580	0.641

Average Index for cod age groups 3, 4, 5, 6.

	Mean	S.D.
1989	0.707	± 0.064
1990	0.676	± 0.080

Total Average Index

	Mean	S.D.
1989	0.633	± 0.179
1990	0.639	± 0.082

TABLE 12. The Condition Factor (C. F.) of cod by age in Div. 3M in July 1989 and July/August 1990.

	1989		1990	
Age	C.F.	No. of cod	C.F.	No. of cod
0	–	–	0.788	14
1	0.989	7	0.812	30
2	1.153	7	0.979	85
3	0.921	242	0.918	44
4	0.918	467	0.960	106
5	0.910	387	0.936	103
6	0.911	55	0.935	86
7	0.906	9	0.938	28
8	0.907	2	0.916	17
9+	0.944	2	0.957	17

TABLE 13. The Overlap Index of Schoener in Div. 3M, July 1989 and July/August 1990 for three groups of cod: Group A (age 1–2), Group B (age 3–5), Group C (age 6–10).

Group	1989	1990
(A-B)	0.518	0.891
(B-C)	0.507	0.569
(A-C)	0.223	0.467

TABLE 14. The Overlap Index of Schoener of the cod groups A, B and C (see Table 13) in different water depths.

	Depth (m)					
Group	150	180	260	360	550	Total
(A-B)	0.593	0.856	0.804	0.537	0	0.785
(B-C)	0.658	0.614	0.650	0.725	0.473	0.593
(A-C)	0.556	0.623	0.468	0.279	0	0.424

Table 15. The cannibalism (%) of cod, by age, in the total stomachs in Div. 3M. July 1988 data from Vazquez, MS 1989.

	Age group					
Date	3	4	5	6	7	Average
July 1988	0.6%	4.2%	9.4%	15.4%	4.5%	3.78%
July 1989	–	0.21%	0.25%	1.8%	–	0.33%
July/August 1990	–	0.94%	6.8%	5.8%	7.1%	4.64%

Predation on redfish

The dominant prey of adult cod on the Flemish Cap in summer was redfish. Their occurrence was high in 1990, but in terms of weight their importance was less

1989 OCI = 0.177, GI = 0.43

1990 OCI = 0.196, GI = 0.39

With the 1990 data the relationship between redfish jaw length and total length was obtained by the regression:

$L_{total} = 6.770 + 6.6392\ L_{jaw}$ (N = 22, r = 0.95, p <0.001,)

The parameters for the cod length and redfish length were calculated for each year. The results were:

1989: N = 58, r = 0.516, p <0.001, y = 4.8917 + 0.20162x

1990: N = 136, r = 0.680, p <0.001, y = 0.7661 + 0.23127x

These values indicate that the increase in length of the redfish prey was related to the length of the predator.

Redfish abundance in the survey trawls by length class was compared with redfish abundance in the stomach contents (Fig. 1). The most abundant size classes were those most preyed upon in both years. This suggested a relationship between the redfish year-class abundance and its predation intensity by the Flemish Cap cod.

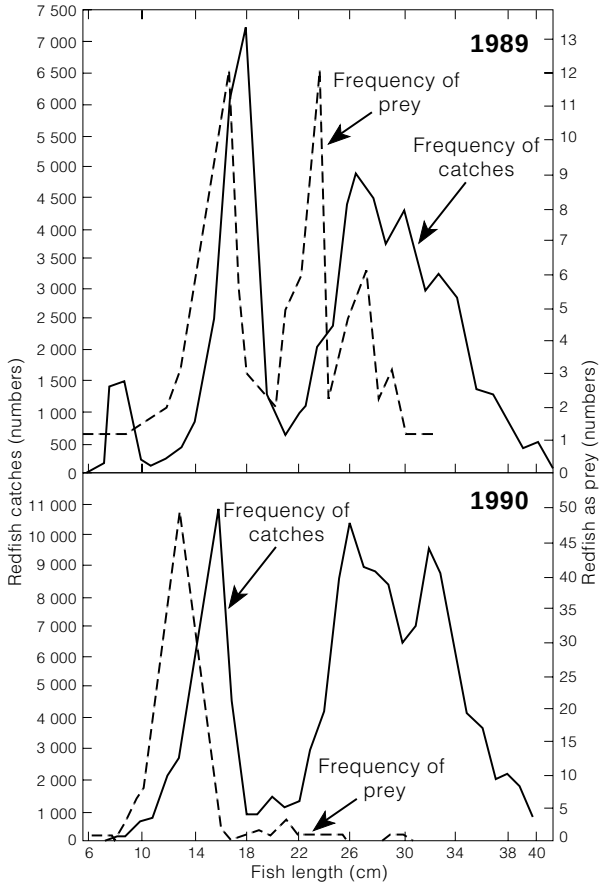

Fig. 1. Redfish abundance compared with redfish in the stomach contents of cod for 1989 and 1990.

Conclusions

a) Cod feeding intensity is high in summer.

b) The cannibalism rate has strong year-to-year fluctuations on the Flemish Cap.

c) The amount and length of prey fishes increase with cod length.

d) The variation of some items (e.g. *Illex illecebrosus*) may reflect their availability in the area.

e) There seems to be a change in diet at age 6 in Flemish Cap cod.

f) Predation is particulary important on small redfish length groups. It begins in age group 0 cod. There is a relationship between cod length and redfish length they prey on.

g) The most abundant redfish year-classes are more preyed on by the cod.

References

ALBIKOSVSKAYA, L. K., and O. V. GERASIMOVA. MS 1989. Feeding food interrelations between cod (*Gadus morhua* L.) and beaked redfish (*Sebastes mentella* T.) on Flemish Cap. *NAFO SCR Doc.*, No. 9, Serial No. N1573, 15 p.

AKENHEAD, S. A. MS 1978. Report of the Canadian Planning Group of the Flemish Cap International Experiment Meeting. St. John's, Newfoundland, 12-14 September 1977. *ICNAF Res. Doc.*, No. 80, Serial No. 5267, 52 p.

KONSTANTINOV, K. G., T. N. Turuk, and N. V. Plekhanova. MS 1983. Food links of some fishes and invertebrates on the Flemish Cap Bank. *NAFO SCR Doc.*, No. 78, Serial No. N744, 24 p.

LILLY, G. R. MS 1982. Cannibalism in Atlantic cod (*Gadus morhua* L.) on Flemish Cap in winter, 1978-82. *NAFO SCR Doc.*, No. 36, Serial No. N525, 5 p.

1987. Cod (*Gadus morhua* L.) on the Flemish Cap feed primarily on redfish (*Sebastes* sp.) in winter. *NAFO Sci. Coun. Studies*, **11**: 109-122.

LINTON, L. R., R. W. DAVIES and F. J. WROND. 1981. Resource utilization indices: an assessment. *J. Anim. Ecol.*, **50**:

MATHUR, D. 1977. Food habits and competitive relationships of the bandfin shiner Halawakee Creek, Alabama. *Ameri. Midl. Nat.*, **97**: 89-100.

PAZ CANALEJO, J., F. J. VAZQUEZ ALVAREZ, A. FERNANDEZ ARROYO, J. M. CASAS SANCHEZ, 3. DE CARDENAS. MS 1989. The feeding of American plaice (*Hippoglossoides platessoides*), redfish (Sebastes marinus) and cod (*Gadus morhua*) in the Flemish Cap during July 1988. *NAFO SCR Doc.*, No. 45, Serial No. N1622, 15 p.

TURUK, T. N. MS 1981. Year-to-year seasonal fluctuations in feeding and biological indices of the Flemish Cap Bank cod. *NAFO SCR Doc.*, No. 76, Serial No. N361, 14 p.

WALLACE, R. K., and J. S. RAMSEY. 1983. Reliability in measuring diet overlap. *Can. Jour. Fish. Aquat. Sci.*, **40**: 347-351.

VAZQUEZ, A. MS 1989. Results from bottom-trawl survey of Flemish Cap in July 1988. *NAFO SCR Doc.*, No. 60, Serial No. N1640, 15 p.

MS 1990. Results from bottom-trawl survey of Flemish Cap in July 1989. *NAFO SCR Doc.*, No. 68, Serial No. N1790, 25 p.

MS 1991. Results from bottom-trawl survey of Flemish Cap in July-August 1990. *NAFO SCR Doc.*, No. 28, Serial No. N1908, 25 p.